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Problems in the Use of Plant Growth Chambers[1]

J. C. Horton and D. C. Foley[2]

Abstract. Plant growth chambers cannot duplicate all of the intricacies of continually changing environments, but properly designed chambers can produce daily and hourly changes in light and temperature with reasonable precision. Gradient, the most objectionable type of temperature variation, can be minimized by increasing air circulation and removing lamp heat as quickly as possible. Bulb age and temperature influence light intensity.

Considerable interest has developed at Iowa State University in the use of plant growth rooms or chambers and several small units were constructed for research and teaching use. Experience has shown that problems in operation or a lack of understanding the methods of use often limit the effectiveness of these chambers. This paper explains how some common problems were solved and attempts to correct certain misunderstandings concerning use.

In this paper, climates are considered to be the changing of environmental variations over a long period of time or the variations in temperature, light, humidity, air movement, which occur during a growing season. Simple, inexpensive equipment can not produce conditions which vary less than 0.5°F or 1 per cent relative humidity. There is no equipment available capable of duplicating all of the intricacies of continually changing environments exactly as these occur in the field. Through the use of elaborate equipment and proper technique certain conditions can be held constant if specific goals justify the cost. Most simple designs can produce daily and hourly changes in light and temperature with reasonable precision. Most important in the use of all chambers is recognition of the repetitiveness of temperature fluctuations due to equipment cycling. Experiments may be conducted under the same conditions at any given time of the year. Temperature fluctuations occur but in a regular and predictable manner.

Greenhouses, by contrast, have wide and irregular fluctuations of heat and light which only approximate conditions in the field. Dependence on solar radiation and a clement external

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temperature remove a large portion of control from greenhouse operators, and repetitive experiments show considerable experimental error. Much of this error can be eliminated by the use of growth chambers, permitting a decrease in experiment size and replication, i.e., more information per plant can be obtained in chambers than in greenhouses. Problems encountered in our chamber are described in this paper and these problems are expected to occur in similar types of equipment.

Temperature

Temperature is perhaps the most important single controlled condition in plant growth chambers. Variations of temperature are classified in three categories: gradient, fluctuation, and drift.

Gradients are temperature differences along vertical and horizontal planes of the box causing uneven plant growth. Differences in flowering, plant height, root development, and dry weight are effects of such gradients. Gradients of as much as 10°C were observed in the chamber during preliminary operation. These were due to low velocity and uneven air circulation and were minimized by use of supplementary fans. Cold air tends to stratify near the floor and must be forcibly mixed with warm air. The increased air flow over plant containers and plant leaves diminished the temperature fluctuations of these surfaces.

Fluctuation is the range of temperatures at any given point over a period of time. The effect of fluctuation is less noticeable than that of gradient since all plants in the chamber are affected more or less equally. Ansari and Loomis (1959) showed leaf temperature variations of up to 20° C. as a result of shading and wind. These values are often approached in the greenhouse. The temperature fluctuation in the chamber described has varied from ± 5° C to ± 2° C, depending upon number of plants, amount of air circulation, etc. Fluctuation is a result of mechanical differential of the thermostat, response time of refrigerant, overshoot of refrigerant, mass effect of plant leaves, plant containers, heat from the lights, etc. Temperature fluctuation in growth chambers is readily reproducible, and plants grown at an average temperature of 22° ± 2° C will be approximately the same as plants grown under similar conditions six months earlier or two years later.

The temperature fluctuation for any chamber can be reduced by using a more sensitive thermostat, heaters to buffer the cold air, a modulated secondary cooling system, increased air circulation, and a chamber within a chamber. These methods are usually elaborate and expensive. Temperature fluctuation gen-

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erally is not a limiting factor in the comparison of small effects over a long period of time.

Temperature drifts occur despite elaborate precautions to prevent them. Changes in the external temperature, operation of the lights, changes in governing thermostats, use of heaters, or operation of other machinery are some of the causes. Much of the heat load is radiant energy and switching off the lights not only affects the heat balance but also eliminates radiation on the sensing element of the recorder or thermostat. Infrared radiation from the light source will cause a temperature difference between the sensing element and the air. Correction of temperature drift is not easily achieved. Frequently, experience with the equipment and an understanding of mechanical operation are the only means of eliminating drift. For example, the dial setting of a thermostat may not indicate the exact make or break point. If radiant energy affects the temperature of the thermostat sensing element, cycling of lights will cause changes in chamber temperature.

Even small drifts, gradients, or fluctuations are sources of difficulty to the researcher who requires an exact constant temperature. Fortunately, most plant growth experiments can tolerate a small, repetitive fluctuation or minor gradients in temperature. Under these conditions experiments can be repeated indefinitely without loss of accuracy. Tolerance of small temperature variations permits use of inexpensive equipment, increasing the scope of utility of plant growth chambers.

Light

A gradient in light exists similar to that of temperature. A fluorescent tube can be considered as an infinite series of points of light. Plants near the bench center are, on the average, closer to more points on this fluorescent tube than plants near the edge and therefore may receive slightly more light. About 90 per cent of the incident light is reflected from the walls which tends to equalize light to the plants near the edges. Increased light at the bench edges can be obtained by use of supplementary bulbs along the walls. The easiest solution, when possible, is the grouping of experimental material in the center of the unit. Light intensities commonly vary about 10 per cent in a horizontal plane. In the field full sunlight illuminates the plant top with approximately 10,000 ft-c. Due to crowding and shading, lower leaves often receive only about 1,000 ft.-c. In a growth chamber, because of radiation from a wide rather than a point source such as the sun and because of reflection from the walls, all plans are generally illuminated equally.

Variation of light intensity is usually no problem since fluorescent lights maintain a fairly uniform output for 75 per cent of their life. However, light intensity variations can occur between experiments for several reasons, the most important of which is bulb temperature. A high rate of air circulation over the bulbs tends to maintain bulb temperature at approximately that of the chamber. Fluorescent bulbs have a maximum output at about 44° C. Changes of 10° above or below this point cause measureable differences in light intensity. At a chamber temperature of 8° C with good air circulation over the bulbs, light intensity will be decreased 75 per cent. Consequently, an increased air circulation often causes variations in light intensity between experiments with different air temperatures. Use of a thermal barrier (transparent shield) for isolation of bulb air circulation from that of the chamber is one remedy, although this requires another cooling system. This method maintains light output under all temperature conditions of the chamber. It is important to keep the thermal barrier clean.

Except for experiments in which the effect of humidity on growth or on plant disease development, etc., is important, humidity variations are not important. The unit described maintains approximate field humidities of 60 to 80 per cent at normal operating temperatures. Humidity control is achieved by passing warm humid air over a cold evaporator. In chilling, condensation occurs and nearly saturated air is discharged at approximately 8° C. A rough rule of thumb is that air doubles in its moisture holding capacity for every 11° C increase in temperature, so warming this cold air up to 19° C would decrease the relative humidity to about 50 per cent. A 75 per cent relative humidity in the chamber is a result of mixing warm and cool air. For most purposes field humidities of 60 to 80 per cent are adequate. This variation is reproducible. A complicating factor could be the addition of outside air, but if only small quantities are added, humidity fluctuations will be kept to a minimum. Relative humidity can be more closely controlled by use of a humidifier or of a dehumidifier. However, dehumidifiers commonly operate at a minimum of 13° C and special arrangements must be made below this temperature. If very close humidity control is required, then equally close control of temperature is also required.

Some cultural practices in growth chambers are of necessity slightly different from those commonly practiced in greenhouses. Optimum conditions for plant growth mean optimum cultural procedures must be followed. Under conditions of uniform high light intensity and favorable temperature and moisture relations, plants grow very rapidly and tend to be succulent. Consequently, it is often necessary to water at least daily and sometimes twice daily. Also required is a high level of soil fertility. We use a nutrient solution every other or every third watering. Response to fertility was perhaps the most important factor in our early experiments and satisfactory plant growth did not occur in greenhouse soil. Under these ideal conditions an optimum environment for insect buildup may exist, and this occurs at a much faster rate than is commonly noticed in the greenhouse. Insect and disease problems can be serious unless immediate control steps are taken. All of the proper cultural practices which should be followed in the greenhouse must be used here to take advantage of the favorable conditions for plant growth.

Growth chambers constitute a valuable tool for investigations of plants. Like any tool, for optimum results they must be used to their maximum efficiency. They are not automatic in operation. It is necessary to learn how to use these chambers to obtain their maximum utility for each experiment. It is equally necessary to assess the specific purpose of an experiment and make certain that the techniques to be followed are appropriate.

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